ECONOMIC ASPECTS OF HURRICANES

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ABSTRACT

Survey data from a variety of interests show the estimated total cost for the protective measures taken in some hurricane-threatened areas. These data are discussed and compared with damage reports from a few recent hurricanes. Costs, savings, and damage figures vary with storm intensities and forecast accuracies. Estimates on how these figures may change within the next decade are included.

1. INTRODUCTION

Actual monetary losses to the economy caused by hurricanes vary considerably. Figures for any one storm may range upward to hundreds of millions of dollars and may be so low as to be of no consequence. Some hurricanes have actually been beneficial.

One normally thinks that the damage figure is a function of the size and intensity of the storm and the population in the area affected. This is very true and does, indeed, account for most of the economic losses. Table 1 shows losses for some famous and some very recent hurricanes. These losses are brought about by the destructive forces of the hurricane. If one were to consider only the most severe storms, the losses would, for the most part, differ by only a small percentage (about 5 percent which can amount to as much as $100 million), regardless of our warning service. This is to say, that the best forecast possible cannot really enable the populace to prevent the structural devastation brought about by a severe hurricane like Carla, Hazel, or Betsy. It is a matter of record that even with excellent warnings, villages and resort areas have been virtually destroyed by the severe hurricanes. In the case of minimal or moderate storms, a good forecast can help to minimize the losses. A poor forecast issued too late, or when too few people were warned, or when too many were over-warned, can add to costs. So any discussion of the economic aspects of the problem must include the capabilities of the warning service. One easy way to do this is to look at the verification of the forecasts of the center locations of storms over the past few years. Tracy [1] has done this and some of his results are shown in table 2.

The history of hurricane forecasting shows that there has been improvement in forecasts from virtually no warning during the first and second decades of this century to the current 24-hr. displacement error of about 100 n. mi. The increase in accuracy the past few years has been very slow and the outlook for any change for the better in the near future is not too encouraging. Dunn [2] has said "while much still remains to be learned about hurricanes, a plateau for the moment in forecasting has been reached." What does this mean in terms of present and future economic loss?

Before pursuing this question, it is best to consider the real meaning of the average 100-n. mi. error. The lateral extent (A) of the affected area for a small hurricane averages only 60 n. mi., but may be as much as 180 n. mi. for a large system. The lateral extent (W) of the warning area must necessarily be greater. Plots of several warned and affected areas reveal that the W/A ratio varies from about 2.0 to 4.0. The ratio varies inversely with the size of the hurricane. Using 3.0 for an average W/A and considering an average hurricane (A equals 100), one concludes that the public must expect a minimum over-warning of 200 n. mi. Over-warned areas in actual practice approximate this figure.

TABLE 1.—*Damage in United States and Canada (in millions of dollars) from a few selected hurricanes*

Hurricane	Damage	Hurricane	Damage
Betsy 1965	$1,419.8	Cleo 1960	128.5
Diane 1955	800.0	Hilda 1964	125.0
Carla 1961	400.0	Florida 1926	111.8
New England 1938	387.1	Isbell 1964	10.0
Donna 1960	386.5	Alma 1966	10.0
Hazel 1954	251.6	Keys 1935	6.0
Dora 1964	250.0	Inez 1966	5.0
Audrey 1957	150.0	Ginny 1963	[1] 0.4

[1] Loss more than offset by beneficial rains.

TABLE 2.—*Twenty-four-hour verification of Weather Bureau tropical cyclone advisories for storms and hurricanes in the southwestern North Atlantic, the Gulf of Mexico, and the Caribbean Sea.* (*After Tracy [1]*)

Period	Number of forecasts	Mean error (n. mi.)
1959–1964	408	112
1964	96	94
1965	67	127

2. CURRENT ESTIMATES OF AVERAGE ANNUAL HURRICANE COSTS

The average annual damage from hurricanes in the United States is about $300 million. (See table 3.) The value would be $200 million if one were to consider only a single hurricane. (There are, on the average, about three hurricanes every two years that move onshore or close enough to produce hurricane conditions over a significant area.)

The figure of $2.5 million for the cost of aircraft reconnaissance is based upon the number of flights during the 1964 season. Slightly more than 150 operational flights were made during the year at $15,000 per flight. This figure may seem high, but does not appear to be excessive when one considers additional costs of training missions prior to the operational flights. The figure is based upon initial investments as well as operating costs and is thought to be a good average for almost any year. (There were 195 planned reconnaissance missions in 1965 but this included several flights not directly related to the warning problem.)

Communication costs are rather minor, but are included in table 3 with an estimate of $0.2 million per year.

Cost analyses for the protection of property (houses and businesses) are very difficult but can be estimated from population figures. A survey of population density along the Gulf of Mexico and the southeastern coastal area of the United States reveals that it is more than likely that at least one metropolitan area (50 mi.) of nearly 1,000,000 people would be included in any hurricane warning (300 mi.). In the remaining 250 mi., density figures would approximate 500,000; 200,000; 100,000; 100,000; and nearly zero for each 50-mi. section. This totals 1.9 million persons placed under the average warning. Major shutter and awning companies in Miami estimate that only 20 percent of the population has made investments in protective measures and manages to put them in use during a warning situation. A cost analysis team [1] of the Weather Bureau has concluded that it takes $5,000 for protective measures for 1,000 people. One concludes that the total protective costs would mount to $1.9 million for an average warning or $2.85 million for the average season.

The same analysis team conservatively estimated evacuation costs at $50 to $65 per family or about $15,000 per 1,000 people. Evacuation is at a minimum if the hurricane is weak to moderate but becomes very large when a severe system threatens a heavily populated area. The number of people who move to places of safety depends upon the degree of community preparedness and organization and upon the extent and seriousness of the emergency as depicted by the wording of the forecasts.

[1] Task team members were Stuart G. Bigler, Phillip A. Dales, Allen F. Flanders, Lynn L. Means, Paul L. Moore, Allen D. Pearson, W. Bruce Ramsay, Loyal P. Stark, Mikhail A. Alaka, Jeff Baker, Lee M. Mace, Alexander F. Sadowski. Also information came from private communication between Robert E. Bailey and the Task Team Leader, W. Bruce Ramsay.

TABLE 3.—*Average annual hurricane costs, United States and Canada (in millions of dollars)*

Hurricane damage	$300.0
Aircraft reconnaissance	2.5
Communications	0.2
Protection (homes and businesses)	2.85
Evacuation	2.0
Special interests	2.0
Satellite	----------
Total	$309.55

There were 150,000 evacuees during hurricane Hilda and 350,000 in Carla, yielding cost figures of $2.25 million and $5.25 million for these two storms. Undoubtedly another $2.5 million were spent for evacuation during Dora and other hurricanes during the 5 years 1960 through 1964. This accounts for a total of $10 million, a yearly average of $2 million. (This figure was exceeded in 1965 when flood waters from Betsy in and near New Orleans remained for a longer period of time compared with floods of other hurricanes in other areas.)

Major special interests near the coast include fishing, civilian and military air terminals, ports, resorts, and installations such as NASA facilities and large refineries, oil rigs, chemical and metal processing plants. A total of six or eight of these may be found within a single warning area with losses for any one ranging from $0.025 to $0.1 million and as high as $0.5 million for the Cape Canaveral or the Houston-Galveston areas. Depending upon the area threatened, this figure may vary from $0.4 to $1.8 million for a single storm and would be $0.6 to $2.7 million for the average season. Attempting to weigh these results, one arrives at a crude estimate of $2 million loss for the average hurricane season borne by the special interests.

Satellite costs have been purposely omitted from the calculations since the observations serve many uses and since only recently have the funds been designated operational.

3. ESTIMATES OF EXTREME ANNUAL HURRICANE COSTS

The information in table 3 allows us to make additional estimates and is repeated in the second line of table 4. The first line of table 4 indicates the current minimum cost during a season if all hurricanes remain far enough offshore so that warnings are not necessary and no damage occurs. The third line indicates the maximum cost that is likely. The $2 billion damage figure seems reasonable since it is only $320 million more than was attributed to the 1955 season and $580 million more than attributed to Betsy in 1965. The fivefold increase in evacuation costs is estimated on the basis of the maximum possible number of evacuees during a severe season. This would approximate 700,000 people, or twice the number that moved to higher ground or places of safety during Carla or Betsy, and account for a $10 million expenditure. Note that the range of the totals in table 4 is great.

Table 5 represents an attempt to project these figures to 1975. Increases in all columns were based upon two

TABLE 4.—*Hurricane costs (millions of dollars)—current extremes for a season (United States and Canada)*

	Damage	Reconnaissance	Communications	Protection	Evacuation	Special	Total
Min.	0	2.0	0.15	0	0	0.2	2.4
Avg.	300	2.5	0.2	2.85	2.0	2.0	309.55
Max.	2000	3.0	0.3	4.0	10.0	3.0	2020.3

TABLE 5.—*Hurricane costs (millions of dollars)—projected 1975 extremes for a season (United States and Canada)*

	Damage	Reconnaissance	Communications	Protection	Evacuation	Special	Total
Min.	0	3.5	0.3	0	0	.4	4.2
Avg.	396–576	5.0	0.4	3.8–5.5	2.6–3.8	4.0	411.8–594.7
Max.	2640–3840	6.0	0.6	5.3–7.7	13.2–19.2	8.0	2673.1–3881.5

TABLE 6.—*Summary of tables 4 and 5 (costs in millions of dollars—United States and Canada)*

	Current	Projected 1975
Minimum	2	4
Average	310	410–590
Maximum	2020	2700–4000

main considerations: the forecast census and the ever-increasing price level. The factors used were 1.1 to 1.6 for the first (derived from various metropolitan, county, and federal government estimates) and 1.2 for the latter (based on estimates of the Economics Department, University of Miami), and were applied to the amounts in the damage, protective, and evacuation columns. Allowing for the increase in the price level and only a small population increase accounts for the first figure of the range. Where population growth is considered to be maximum (southeastern Florida), the factors used were 1.6 plus the price level increase, and this gives us the second figure of the range. All other increases noted in table 5 are minor, if one views the problem from the standpoint of percentage increase. Table 6 is a round-off summary.

4. QUESTIONS AND COMMENTARY

Many questions arise from a study such as this. Some are difficult to answer; the most obvious ones, with some commentary, follow.

What Is The Cost of Unnecessary Warnings?

Referring to table 4 again, one might say that errors of commission would cost nearly $7 million (sum of protection, evacuations, and special interests) for the average season and $17 million when the maximum number of severe storms threatened but never made landfall.

How Much Is Saved by the Hurricane Warning Service?

$300 million represents the damage done during the average season with only 20 percent of the people taking protective action. One might conclude that the damage would be $375 million if it were not for this action. But this is not quite true, since the protected have losses too—let us say 50 percent—bringing the amount saved down to $37.5 million. This figure is reduced more when one considers the over-warning because of our inability to pinpoint landfall. This means that while we are saving $37.5 million we are also incurring unnecessary expenses of one-half, two-thirds, or three-fourths of the $7 million depending upon the size of the hurricane. Actually, it would be a little less than these ratios, since complete evacuation would not be recommended over the entire warning area. It seems reasonable to estimate that the warning service saves in excess of $32 million while spending or causing to be spent an additional $7 million during the average season.

The same arithmetic can be applied for a severe season when maximum costs and damages occur. Based on the 20 percent again, the damage might amount to $2500 million if property were not protected. But here the difference of $500 million would certainly be reduced by more than 50 percent because of the severity of the hurricane. It is estimated that even though 20 percent of the property was secure, the best possible warning would not save more than $100 million. In this case we are spending or causing to be spent only an additional $11 million over the average season or $18 million more than would be spent during a season when all storms remained far at sea.

Summarizing the last three paragraphs, we see that (a) gross forecast errors of commission would cause unnecessary costs which might range from $7 to $17 million; (b) the hurricane warning service saves about $25 million during an average season; and (c) the service might save as much as $100 million during a very active season.

As far as the general economy is concerned, losses are losses, regardless of the amount returned through insurance. Many losses are recovered on the local level, depending upon the amount of insurance and other sources of assistance such as governmental and charitable organizations. Because of these monies, a few areas have actually been known to boom after a disaster. Recoverable losses in Florida, through insurance, for hurricanes Donna, Cleo, and Betsy were about 30, 50, and 25 percent respectively.[2] These recovery figures are not very meaningful since they depend upon the type of damage. A hurricane which produces a great storm surge usually causes a large loss of which very little is recoverable. One can say that in Florida, as in other areas, most property is mortgaged which requires insurance. This type of insurance covers wind damage or damage resulting from wind damage to the structure and usually the contents.

[2] Sources of these figures were Florida State Insurance Commissioner and the Florida State Civil Defense Survey Teams.

How Can Hurricane Losses Be Reduced?

The best to be hoped for is through the modification of the track or intensity or through speeding the dissipation of the tropical cyclone. This may not come about during our lifetime, although there are those who feel that very important gains will be made within the next 10 years. Meanwhile, we should place more emphasis on public education in the utilization of available services and continue our efforts to aid and encourage community preparedness. We should support and encourage better building codes patterned after those in Dade County, Florida. We should try to improve our forecasts, although the outlook for this is not too good over the next few years. Along this line, our attention should be directed toward more carefully worded, concise, and timely warnings.

In conclusion, there are two important unanswered questions which need attention. Should our best building codes be strengthened and should there be special ones for the most vulnerable places? Would a cost-benefit analysis show it to be economically more feasible for the various Counties and States to adopt these proven building codes or for the government to construct local storm surge protective facilities along the Atlantic and Gulf coasts?

REFERENCES

1. J. D. Tracy, "How Accurate Are Hurricane Forecasts?" *Mariners Weather Log*, vol. 9, No. 4, July 1965, pp. 113–115 (also Attachment 12, The Interdepartmental Hurricane Warning Conference, February 1965.)
2. G. E. Dunn, "The Nation's Hurricane Warning Service in 1965," *The George Washington University Magazine*, Federal Issue, Summer 1965, p. 26.

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NEW ESSA PUBLICATIONS

Report of the National Committee for Clear Air Turbulence to the Federal Coordinator for Meteorological Services and Supporting Research, Washington, D.C., 1966, 51 pp. Price: 35 cents.

An evaluation of the requirements in the field of clear air turbulence and general and specific recommendations relating to measurements and observations, remote detection, pilot/aircraft response, and forecasting and dissemination of forecasts.

COAST AND GEODETIC SURVEY

"Tables of Folded-Sin x/x Interpolation Coefficients," by L. F. Bailey, *Research Paper*, Washington, D.C., 1966, 161 pp. Price: $2.75.

Tables of folded-sin x/x are presented, allowing interpolation between equally spaced values sampled from a continuous function, even though not specifically defined. A comparison with sin x/x interpolation is included, and precautions to be observed to avoid frequency distortion arising from improper use. The computer program used in generating the tables is also presented.

ENVIRONMENTAL DATA SERVICE

Climatological Data for Antarctic Stations, No. 8, January–December 1965, Washington, D.C., 1966, 86 pp. Price: 50 cents.

Summarizes for 1965 conventional surface data for three stations, Amundsen-Scott, Byrd, and Eights, and rawinsonde data for Amundsen-Scott and Byrd. Rawinsonde data for Eights station for 1962 and 1963 and surface data for Eights for 1961–1964, not previously published, are also included.

WEATHER BUREAU

"Probable Maximum Precipitation, Northwest States," *Hydrometeorological Report* No. 43, Washington, D.C., Nov. 1966, 228 pp. Price: $1.75.

Presents generalized estimates of probable maximum precipitation over the Columbia River Basin and the coastal drainages in Washington and Oregon. The States of Washington, Oregon, Idaho, and portions of Montana, Wyoming, Utah, and Nevada are included.

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